AN EXPERIMENTAL STUDY
OF
SIMULTANEOUS STIMULATIONS
OF THE
SENSE OF TOUCH.

BY

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~~Fellow in Clark University~~.

REPRINT
FROM
THE JOURNAL OF NERVOUS AND MENTAL DISEASE,
MARCH, 1893.

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AN EXPERIMENTAL STUDY OF SIMULTANEOUS STIMULATIONS OF THE SENSE OF TOUCH.

BY WILLIAM O. KROHN, PH.D.[1]

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THIS study of the simultaneous stimulation of several portions of the dermal area was undertaken with a view to pursuing four lines of investigation, as follows:

1. To discover the relative sensitiveness of different portions of the skin.

2. To find the nature and direction of the errors in localization.

3. To study the influence of attention upon the localization and interpretation of simultaneous touch stimulations. Also the investigation of the problem of attention, with especial reference to the question of how many sensations of touch the mind can attend to, or grasp, at one time.

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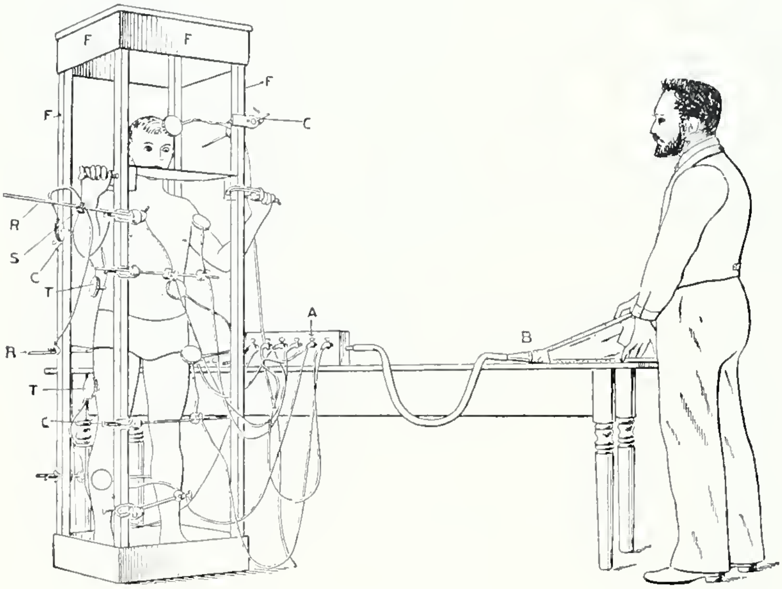
[1] In the portion of the experimental work done at Clark University, Mr. T. L. Bolton, the able laboratory assistant, co-operated throughout, giving a large amount of time and supplying many valuable suggestions as the work progressed. The writer takes this method of thanking him for his invaluable assistance, so freely and generously given.

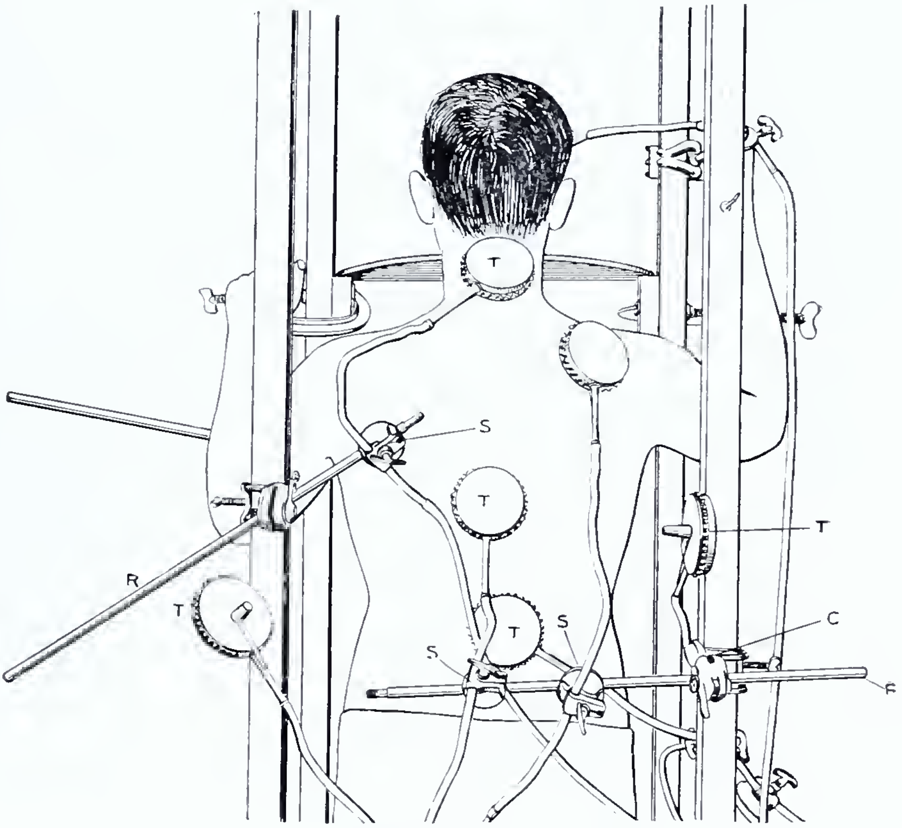
4. To examine the effect of practice. Can the skin be educated to greater sensitiveness and accuracy in localization?

The experiments upon which this study is based number many hundreds, and were made upon ten different persons, who kindly lent themselves as "Versuchsthiere." The majority of the experiments were made in the psychological laboratory at Clark University; and the writer desires to thank Prof. Sanford for assistance in devising the apparatus, as well as for his kindness, both in serving as a subject for experiment and in rendering many timely suggestions as the work progressed.



Not only was much interesting material gained that has direct bearing upon the four lines of investigation already indicated, but the experiments also disclosed, incidentally and accidentally, many other important facts, having a bearing upon other lines entirely unthought of at the outset, but which, nevertheless, opened up some of the most fruitful subjects for further investigation. The first part of this article is descriptive, and therefore general; the second part partakes more of the nature of a tabulated record of experiments.

Literature.—There is no literature bearing directly on this particular field of which the writer has any knowledge. If the field has ever been investigated, the results have, at any rate, never been recorded. No experiments having been made in this line, there was no clew to apparatus; and the first problem we had to confront was the construction of suitable apparatus with which to pursue our investigation.



Apparatus.—The apparatus used can best be described in connection with the accompanying cuts.

The upright frame, *F*, is solidly made of wood, and securely fastened to the floor. The upright standards (*f,f*) are of such a thickness as to permit the fastening of the clamps (*c,c*), of which there may be a large number.

These clamps are after the Otis C. White pattern, with ball joints, and allow the adjustment of the half-inch nickel rods (*r*, *r*) at any angle. On these rods are sliding clamps (*s*, *s*), which admit a variety of adjustments; and through these clamps lead pipes are inserted (lead being chosen on account of its flexibility). These lead pipes are soldered at one end to tambours (*t*, *t*), and at the other end is connected by means of rubber tubing to the air-box, *A*, which in turn is connected with the bellows, *B*. The tambours are constructed in the ordinary way—flat tin-cups, over which bits of sheet rubber are stretched. When the rubber is expanded, by the forcing of air into the tambours, it presses against a cork, pushing it outward at least an inch. Corks were chosen because they come nearest to arousing pure and simple touch sensations. Ten tambours were used, thus making it possible to stimulate ten different spots on the dermal area at the same time, when air was forced through the air-box into these tambours. There are ten stop-cocks on the air-box, by means of which the air could be kept from passing into any one or more of the tambours in any experiment. A mouth-board was provided, in which the subject could fix his teeth in order to assist him in holding still.

Method of Experiment.—The subject was blind-folded, and took his place within the frame, keeping as nearly still as possible. The tambours (seven, eight, or all ten) were adjusted so that the corks were within one-half inch of the skin of the subject at different localities. The signal, "Ready," was given, and then the bellows compressed, thus forcing the air into the tambours, and thereby causing the corks to press against the skin. They immediately withdrew from the skin of themselves on account of the elasticity of the rubber diaphragm of the tambours. The subject then either himself indicated the exact point (as he thought) touched, or else let the operator pass a pencil or point over the skin till it come to the spot which the subject regarded as the one touched. In the later and more accurate experiments, the spots really touched, and those regarded by the subject as having been touched were marked by a soap pencil or dry lamp black. In all cases the direction and amount of error were carefully observed and recorded. The subject was never allowed to become fatigued or chilled, as it was found that such influences always vitiated the experiment. In the first place, with a new person acting as subject, general tests were made, any kind of combinations or any sort of group of spots being used to determine the general dermal sensibility of the subject and his powers of localization. After this a series of ten tests (in some cases fifteen) were employed, each test embracing seven points on the skin—different features characterizing each of the tests. These groups or tests were repeated over and over again, always in a different order, and were such as the following:

TEST I. (Three pair bilateral and one unilateral touch).

Outside left ankle.
Outside right ankle.
Right side B.
Left side B.
Tip left shoulder blade.
Tip right shoulder blade.
Middle forehead.

TEST II. (All on right side except one).

Left elbow.
Right arm outside (upper).
Right nipple.
Top right shoulder.
Front right thigh.
Outside right calf.
Right instep.

TEST III. (On line through navel and bilateral).

Right hip over joint.
Left hip over joint.
4 inches to right of navel.
4 inches to left of navel.
3 inches to left of small of back.
3 inches to right of small of back.
Great toe of left foot.

TEST IV. (Bilateral).

Front of right knee.
Front of left knee.
Front of right shin.
Front of left shin.
2 inches above left nipple.
2 inches above right nipple.
Back of neck.

TEST V. (In groups).

Back of right calf.
Outside of right calf.
Front of right calf.
Top of right shoulder.
Right elbow.
Right wrist.
Left side of neck.

TEST VI. (Grouped in pairs).

Left knee front.
Left knee outside.
Left calf behind.
Right calf outside.
Back of right hand.

TEST VII. (Joint).

Left hand, knuckle of little finger.
Chin.
Right foot, joint of great toe.
Left ankle, outside.
Right wrist joint.
Right elbow.
Right shoulder.
Left knee.

Results. 1. Indubitable evidence as to the relative sensitiveness of different portions of the skin.

a). Skin over the joints much more sensitive than that at other localities on the dermal area. In the joint group (*e.g.*, group VII) it was not unusual for the person to correctly localize six or seven out of a possible eight. The following is the record on joint groups:

Person.	Whole No. of Joint Touches.	Percent. corectly Localized.	Percent. of Errors.
W. O. K.	512	78	22
T. L. B.	211	72	28
F. A.	399	74	26

While for the same persons, the general record on all localities touched was 62 per cent, 64 per cent, and 68 per cent respectively, for correct localization.

b). Touches on the back of the body are more distinctly felt, more clearly remembered and, therefore, better localized than on the front part of the body. Thus, out of all the touches on the front and back respectively, we gather the following records:

Person.	Whole No. of Touches.		Percent. cor. localized.		Percent. of Errors.	
	Back.	Front.	Back.	Front.	Back.	Front.
W. O. K.	200	200	69	55	31	45
F. A.	95	111	67	54	33	46
D. F.	40	93	62	57	38	43

Perhaps the general fact that the skin on the back of the body is more sensitive, and localizes better than that on the front of the body, may have some bearing upon the oftstated hypothesis, that the primitive man assumed the horizontal position of quadrupeds instead of the erect position, and that the back through generations of exposure was made to better localize the touch stimulations upon its dermal surface.

c.) Localizations of the dermal sensations are better for points not on the median line than for those that are. Thus, for example, out of 401 touches in the case of S., 130 were on the median line and 271 on other localities.

Of those on the median line, but 34 per cent. were correctly localized, leaving 66 per cent. representing the errors, while on other localities 68 per cent. were correctly localized and but 32 per cent. were errors.

d.) On the left side of the body we do not localize the dermal sensations so correctly as on the right side. Thus, out of 500 touches, 250 on the left and 250 on the right side of the body, there were 38 per cent. wrongly localized on the right side, while on the left there were 43 per cent. incorrectly localized. Thus, 53 per cent. of the whole number of errors were on the left side of the body. This is contrary to the results of the experiments of Hall and Hartwell ("Mind," No. XXXIII.) upon the relative sensitiveness of the right and left sides to motion on the skin.

As one of many specific examples, this might be cited: In Test IV. there were touches inmediately above both nipples; but in the large majority of cases of incorrect localization, in this particular test, the mistakes were made with reference to the touch above the left nipple. However, the interesting fact was noticed that the touch upon the left had the effect of pulling toward it the sensation on the right side; and the touch was, therefore, localized nearer the median line than it should have been, or nearer than it would have been, were there but a single touch, and that on the right side.

(*e.*) On hairy portions the localization is much better than at those localities not covered with hairs. This is especially prominent as a factor if the hairs have been shaven, as was the case with one of the subjects. In this instance the skin over the thighs and calves, after the shaving of the hairs, was so sensitive as to vitiate the experiments, because the sensations received at these regions were so intense and pronounced as to cause the mind to lose the sensations at the other stimulated portions of the skin.

(*f.*) A difference in the power to correctly localize was found in those portions usually covered with clothing, and those not so covered. Except in case of the joints, the portions not covered would localize the sensations with greater correctness.

The above facts furnish unquestionable evidence for the assertion that the accuracy of the localizing power varies widely in different regions of the skin surface. And the proof is even more direct than that gained by the old method of experiment, in which the observer noted the least distance which must separate two objects (as the points of a pair of dividers) in order that they may be felt as two.

2. *Nature and Direction of Errors in Localization.*—These errors were of four kinds: (*a*) errors of extension, in which the sensation was projected away from the median line toward the extremities; (*b*) vertical errors *d'élévation*, in which the sensation was given a place higher than the one actually stimulated; (*c*) vertical errors *d'abaissement*, in which the sensations were localized at a point lower than the one at which the stimulations were applied; (*d*) miscellaneous errors, such as lateral errors on the limbs, *e.g.*, feeling a sensation on the *back* of the right calf when it was on the ouside of the right calf but in the same horrizontal place.

Then as to direction of the errors.—Out of every one hundred errors of localization in our experiments, 42 per cent. were errors of extension, and the average amount of error was 4.36 inches; 31 per cent. were errors *d'élévation* with the average amount of 3.36 inches; 20 were errors *d'abaissment*, average 4.19 inches; while 7 per cent. would be classed as mixed or miscellaneous errors. Thus both the largest number as well as the greatest amount of error fall into class (a)—errors of extension or projection. The more the stimulations are scattered over the dermal area, the more correct is the judgment of the subject as to locality. In case of legs and arms, touches on the joints are better localized than on the fleshy portions of the limbs; more acutely felt and localized across the long axis of a limb than within this axis; more correctly localized on the limbs than on the trunk of the body; better localized on the back than on the front; and better localized when not on the median line.

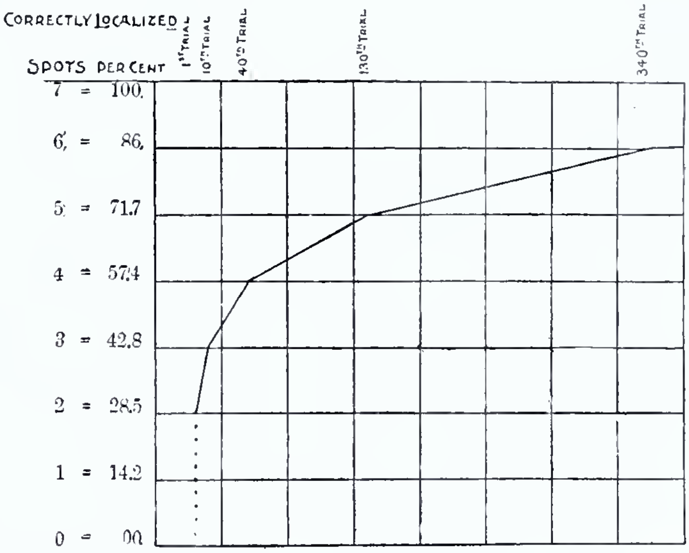
The general rule might be this: *The localizing power is delicate in proportion as the skin covers a more moveable part of the body, and is also more acute when the pressure stimulation is only strong enough to cause an appreciable sensation than when it is more powerfully impressed.*

3. *Attention plays a most Important Part in the Localization of these Simultaneous Stimulations of the Dermal Surface.*—For example, if the subject be told there will be no touches upon the legs, he will be enabled to give a greater number of correct judgments than if he expected the pressure stimulations to occur anywhere on the whole dermal area. And in a group test, like No. III. (in which six of the touches are on a line through the navel and bilateral, and thus grouped rather closely together) the subject could not localize the touches as well, because he expected them to occur all over the body. A test group like I. was always much better localized than group III. or V.

Close attention of the most intense degree is always a prime requisite for anything like success in correctness and accuracy of localization of the simultaneous pressure stimulations. With the varying degrees of attention there are varying results—from a hazy, cloudlike and very general sensation of being touched somewhere on the skin, with no idea as to the number of touches, to the correct and positive localization of the maximum number of simultaneous touches. If the points are somewhat scattered, and the subject attends closely, the mind will grasp clearly and distinctly, and localize correctly six out of seven simultaneous touches. One or two exceptional and star records were made in which the subject was able to recognize and locate every one of the stimulations in a group of eight, and that, too, very early in his individual series.

4. *The Effect of Practice is very Noticeable.*—The skin can be progressively educated to localize sensations of pressure more and more correctly. At first, in the different individual series, the subject could generally localize but two out of seven, but after a number (130)

of "sittings" (or more properly speaking, "standings"), he had no trouble in localizing five out of seven. The improvement from practice is very rapid. The accompanying "practice curve" shows in a graphic way the educability of the skin with reference to localization of the simultaneous pressure stimulations, for one individual.



5. *Dermal After-Images.*—In our experiments it was found that the after-images of touch were more pronounced and endured for a greater length of time in some localities than in others. Thus the after-images on the backs of the calves sometimes endured as long as five minutes after the touch stimulus was applied. Oftentimes the after-image was felt more clearly and localized better than the original stimulation. The fact of the matter is, that the subject many times would use the after-images as a clue in his endeavor to localize precisely, and after naming the touched spots, would, if permitted, correct, by means of the dawning after-images, his original statements as to the localities stimulated. Sometimes the after-image would be so strongly felt as to vitiate the succeeding experiment unless a considerable amount of time intervened, for the subject would locate pressure stimulations at certain spots, which supposed stimulations are clearly nothing but after-images

of the touches that composed the groups or series immediately preceding. The after-images endure for a longer period on the hairy portions of the skin, especially after the hairs have been shaven. The more pronounced and positive after-images occur in the following localities of the dermal surface, the sequence or arrangement corresponding to the natural order beginning with the part in which the after-images are most intense: calf of leg (behind), ankle bones (outside), shins, nipples, instep, and tendons.

6. *Fusion of the Pressure Stimulations.*—Perhaps the most remarkable result of our experimental study has been the discovery of a large amount of evidence with reference to the fusion of two or more stimulations into one single sensation, and the localization of this sensation at a point removed from either of those at which the stimulations were received. The facts bearing upon this subject gathered from our investigations are remarkable both for their number and their striking character. We herewith append a large number of cases in support of our statement. In Test III. there are two points stimulated on the front of the abdomen—one four inches to the right, and the other in the same plane four inches to the left of the navel; the touches therefore being eight inches apart. Yet in three instances, one of our best reactors, E. C. S., indicated but one touch on the abdomen, and that directly on the navel, midway between the two points actually touched. With J. A. B. there was also the same case of fusion. E. C. S. fused two touches, one at a point directly under the armpit on the right side, and the other at the tip of the right shoulder blade—into one sensation, locating it at a point midway between them but lower down on the trunk. L. R. fused the two stimulations—at the top of the right shoulder and the tip of the right shoulder blade, respectively—and localized the sensation as coming from a point midway between the two. In six instances the same subject fused into one sensation the two touches, at the back of the right calf behind and the outside of the right calf, in the same horizontal plane. Nearly every one of the

ten subjects would, at the same time, in his individual series, fuse these two into one (cf. Test VI.). It was also very common to fuse the two touches at the outside and front of the calf into one sensation, locating it as coming from a point a little lower but on a line between the two actual stimulations. One reactor felt as one and located at the knee (outside) the two touches upon the front of the right thigh and outside of the right calf respectively. And still another subject, in Test III., where there are two touches on the skin over each hip joint and two touches three inches on each side of the spinal column, three inches from the small of the back, did not feel these four stimulations properly, but experienced only two sensations and localized them as bilateral and on a point three inches directly back of the hip joint on either side.

Mention must also be made of the cases of partial fusion in which two stimulations were felt as two, but at points much nearer together than the points actually touched. Thus, one subject localized the two touches which occurred at the tip of each shoulder blade as bilateral, but each was two inches nearer the spinal column than the actual points stimulated.

This is but one of many examples which might be adduced. A more complex case of fusion is the following, in which there were three touches, one on each nipple, and one on the skin over the breast bone and in the same horizontal plane as the nipples. The subject felt the three as two, and located these two on the same line but three inches nearer the median line than the nipples, that is, he localized them as two coming from points about midway between either nipple and the point over the breast bone in the median plane.

7. *Diffusion.*—There were also results diametrically opposed to the cases of fusion just cited. These cases of diffusion were, however, less frequent in occurrence and less striking in character. Thus, one subject being touched by a single cork, at a point immediately under the armpit (left side *a*) designated two localities about four inches apart. This case will seem the more remarkable when it is stated that in this same identical experiment

in which the sensation was spread, the individual also fused two touches (at the knee and ankle) into one, located between the two. In another case the right nipple was one of the points touched. The touch was felt as two immediately above and below the nipple, four inches apart, and at the same time the same E. C. S. felt a touch on the tip of the right shoulder blade as two located in a vertical line and also four inches apart. J. A. B. felt as two a touch on the skin at a point on the spinal column just midway between the two tips of the shoulder blades. These psuedo sensations he localized as coming from the tips of the shoulder blades. With the same subject there was a single touch on the right nipple (Group Test II., cf. above), but he felt this as two, one four inches above the nipple and the other in a direct vertical line six inches under the nipple, or in other words, this single stimulation was diffused into two, which the subject regarded as *ten inches apart*. One reactor when stimulated at the second joint of the great toe on the left foot, felt two sensations on the same foot at the ankle bone and little toe respectively. Also touches upon the back of the hand or on the knee cap were often felt as two. Many other illustrations might be cited but these will surely cover the case in point.

8. *Dermal Sensations of Subjective Origin, or Imagined Dermal Sensations.*—By these we mean those cases in which the mind projects a sensation, and definitely localizes it as coming from a given point—a sensation which he feels as distinctly as if there were an actual pressure stimulation at that point. The psuedo or purely subjective sensations have the same "local sign" or "tone" as those arising from actual touch at the same localities. We have no explanation to offer—we can only submit the facts at this stage in our experimental study. Perhaps a very few could be accounted for as being after-images of previous stimulations, but only few—by no means all. Some specific examples might be of interest. Thus in Test II. one subject felt a touch on the left nipple (corresponding to an actual touch on the right nipple) when there was no such touch. In the case of

Test IV., the same subject felt a touch on the left forearm just above the wrist where there was no actual stimulation. Another subject, F. B. D., in Test II., indicated an additional touch on the left calf (outside); in Test III., he located an extra one on the right foot; and in Test IV., he located two more, one at the tip of the shoulder blade and another on the top of the shoulder, both on the right side. *In all these cases there was no objective stimulus to which the sensation might be attributed.* Likewise A. F. indicated in Test II. an additional touch upon the right wrist; and in Test III. localized one on the top of the left shoulder. In neither case was there any objective basis for the sensations. In one test, where there was but one actual touch on the limb, and that on the front of the right knee, J. A. B. felt two additional touches, one of which he localized on the left shin, and the other on the left arm just above the wrist joint. In Test IV., the same individual felt one on the front of the left thigh, and the other on the abdomen to the right of the navel, where there was no objective stimulation whatever at these localities. In the same Test IV., E. C. S. felt an additional touch, on the right foot, which he spoke of at the time as quite pronounced. The same person, in Test VI., indicated two extra ones, on the left calf and ankle behind respectively. This is all the more interesting from the fact that at the same time in the same test he he fused four sensations into two—those on the left knee front and left knee outside, as well as those on the right calf behind and the right calf outside; he fused these and localized the sensation product at a point just between the two actually stimulated. We wish to further pursue our experiments on this special line—the imagined dermal sensations—before attempting anything like an explanation. First examine, then describe, then explain, is ever the best method of procedure in scientific research.

9. *Bilateral Asymmetry of Function in Dermal Sensations.*—While as a rule bilateral touches were easier localized than touches in the unilateral or mixed groups, there are many cases in which bilateral touches were localized

very poorly indeed. For example—in Test IV., in one instance the touch near the left nipple was localized three inches too high, while in another instance it was three inches too low. In Test I. there was another instance in which the touch on the left ankle bone was localized three inches lower than the one on the right. Most of these mistakes occur with reference to the touches upon the left side of the body; and of two bilateral touches, the one on the right is more likely to be felt and remembered than the one on the left.

10. *Translocation.*—This term refers to those cases in which the stimulus is applied at one point on the surface and felt at a point exactly opposite. Thus a case of translocation of the dermal sensations on the limbs would be this one, taken from our records, in which a touch applied to the front of the left thigh was felt at a corresponding point on the back of the thigh instead of at the point actually stimulated. Or this—in which the actual touch was applied at the tip of the right shoulder blade but localized at a point almost directly in front near the right nipple. Several cases are recorded in which touches on the outside of the knee or ankle were localized at the corresponding points on the inside of the leg. There were a few isolated cases in which touches on one side of the body were localized at a corresponding point on the opposite side, *e.g.*, a touch on the left foot was felt as coming from the instep of the right foot. But such extreme cases are very infrequent.

This closes our study at the present stage of experimentation. It must be remembered that all these are experiments upon *simultaneous* pressure stimulations. The writer is now engaged in a study of *successive* touches in which a small-time interval, *e.g.*, $\frac{1}{25}$ of a second, elapses between each two applications of the stimulus. These experiments now being made are with special reference to the study of the physiological memory of the skin and are carried on with especially constructed pieces of apparatus.

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